ENLARGING THE CONSUMPTION OF FOREST PRODUCTS

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ENLARGING THE CONSUMPTION OF FOREST PRODUCTS

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THE CHANGING DEMAND FOR FOREST PRODUCTS

There is the same call for aggressive, farsighted action in maintaining the consumption of forest products that there is in providing for the growth and protection of timber stands.

Upon the unparalleled timber resources of the United States hitherto have been built industrial, financial, and commercial activities of enormous magnitude, which in capital invested, in value of products, and in labor employed, rank collectively in the foreground of our national developments. Such facts, considered alone, might be taken as a guarantee of the permanent place of forest commodities in our civilization. But present industrial trends outweigh the past in obtaining a realistic picture of forest industry and its economic importance to the country.

Wood in the past has for many purposes been practically the only available material for use, and this has been a controlling factor in pioneering and in the middle period of development in the United States. Under primitive conditions, wood is the only fuel. Hundreds of logs make the dwelling.

Even for crude machinery, wood serves as a ready makeshift. At a later stage, with railroads opening up new farming, forest, and mining territory, forest and sawmill products came into their own for the settlement of the countryside and the rapid erection of whole towns, with their full complement of stores, warehouses, and first industrial plants. The wooden house becomes in a measure standardized and is then often elaborated as an expression of wealth. Such developments are perfectly familiar to Americans. They mark a very recent period of our history. Continuing to some extent even now, they help to explain our relatively high per capita consumption

of wood. But the projection of an unlimited and uncontested use of wood into the future is a matter of uncertainty that must be frankly faced.

The declining trend in lumber markets since 1906 is amply presented elsewhere in the chapter of this report entitled "Timber Resources and Requirements." We cannot overlook the facts that had the per capita lumber consumption from 1899 to 1909 continued, the 1929 gross consumption would have been almost twice what it was, and that in an era of prosperity and building activity perhaps never reached before (1920–29), when the consumption of all other major building materials was greatly increased, gross lumber consumption actually decreased or barely held its own.

A review of present facts and tendencies of the market situation leads to the inevitable conclusion that without positive and determined action to enlarge them, our requirements for forest products in the future may not be what they have been in the past, either in form or in quantity; that a high per capita consumption of forest products in the past is no guarantee of high consumption in the future; and that new forms and economies in the use of the basic raw materials, such as are represented by developments during recent years in steel-skeleton construction, veneered coverage, and large-size structural units of light weight, may upset the most exact predictions based on past experience. We must recognize that uses long held by wood are being contested both by old materials refined by science and by new materials of scientific origin, promoted with the aid of extensive technical knowledge of their properties. Metal lath and window sash, synthetic boards, all-metal automobile bodies and airplanes, steel desks, metal doors and trim, composition floors, concrete bridges and piling, asbestos and tile roofing, metal poles and posts, synthetic wood alcohol—these are but a few illustrations of the prevailing tendency toward substitution. The real and constant quest of modern Americans for technical progress and improved products and service are factors that must be candidly faced in planning for the future. If in the case of any material, wood included, it is assumed that it will stand for all time on the strength of its past and present state of perfection, there is almost a certainty, because of the increasing interchangeability of materials, that its use will diminish. There is an essential distinction to be drawn here between the need for wood as a cheap raw material for conversion by industry into salable commodities in a highly competitive field, and wood or forests essential in themselves for other purposes.

THE IMPORTANCE OF MAINTAINING AND INCREASING CONSUMPTION

In future plans for forestry, persistent effort must be put forth to retain, to recapture, and to expand the market for forest products, which means the use of modern competitive methods that have come into play in the development of other materials; nor is the motive solely one of profits to particular forest-using industries.

Forest markets are an essential factor of land use. With action which will bring assurance of future markets large enough, diversified enough, and profitable enough, we can look forward to the permanent and profitable use of millions of acres of land for commodity forest

purposes—land that seems to be suitable for no other purpose than timber growing, or for timber growing in connection with other services that a productive forest can render. Future supplies of merchantable timber need not be sacrificed in hasty efforts to liquidate the entire forest wealth of the country. Wood, a resource of basic importance in a wide variety of uses and one that is indefinitely renewable, can be kept available for the American public, thus insuring the advantage of possessing an abundant raw material upon which to draw both in normal times and in national emergencies.

Through assured markets for forest products, hundreds of thousands of workmen will be benefited both by a continuing wage and by the social values of employment in a settled location. Huge investments of capital in timber lands and industries can be kept productive. Local governments can be assured a steady basis of tax revenues, and States and communities can benefit from a continuing source of wealth. A vital problem of farm land can be solved. In farm woodlands there are over 126 million acres, an area nearly one fourth as great as the acreage of improved farm lands.

Beyond and in addition to the foregoing, there is one consideration that alone would justify public interest in the broadening and stabilization of forest markets. This is the investment that the Government has at stake in its 140,000,000 acres of national forests in the United States. With an ownership of more than 550 billion board-feet of timber, worth, at a conservative estimate, half a billion dollars on the stump, every 10 cents per thousand feet change in stumpage value means a $50,000,000 change in the value of these holdings. And stumpage values, of course, will go up or down as markets for forest products go up or down.

ACTION PROPOSED AND RECOMMENDED

In the effort to hold, recapture, and expand the market for forest products, definite accomplishment along four distinct lines is imperative: First, a lowering of costs to the consumer; second, an increase in satisfaction in the use of the products through improvement of properties and qualities; third, the development of new products or modified products; and fourth, the promotion of popular acceptance and use of the products by all legitimate contributory means that may be effective.

Fortunately, there are many favorable opportunities for such efforts. In the first place, markets for forest products have been proving unprofitable or unsatisfactory, at least in part, because of improper selection of material, improper preparation for use, and improper design of the commodity or structure, and not because the material lacked the intrinsic properties desired. In the second place, chiefly because of an abundance of raw material, the forest-using industries have in the past utilized only from one third to one half of the actual material grown or available on the stump. The remaining one half to two thirds, which costs as much to grow as the portion heretofore used, has been put to no economic use. This so-called waste material holds great possibilities for the production of commodities which can return an added profit to the production costs of stumpage. Further, for any given production, efficiency in utilization means reduction in forest cut. Such reduction of cut becomes at once translated into

increased forest supply. This increase is of a form and character of immediate rather than potential value. It is cumulative without additional expense. A saving made today is repeated tomorrow and perpetually thereafter. A board foot saved by improved utilization becomes a board foot saved annually, thus augmenting our waning timber supply, while also lowering production costs.

In the light of these objectives, the retention and enlargement of forest consumption and markets is a problem of industrial efficiency in production and distribution, of scientific and technical advance in the improvement of forest products, and of general attitude and policy reflecting public interest and support for the economic success of forestry. The specific lines of action that are proposed here will be taken up in that order.

INDUSTRIAL ORGANIZATION AND PRACTICE

Low production costs and a high degree of satisfaction to the consumer call for important changes in organization and practices with respect to forest holdings. In the face of a rapidly shrinking supply of standing timber, the wood-producing and wood-using industries from New England to California are confronted chronically with flooding of markets and a profitless and demoralized price structure. The results are seen in wasteful cutting and conversion of timber stands, in sacrifices of quality strongly reactive upon the reputation of the product, in hurried liquidation of present properties, and in short-sighted disregard of regrowth. Examination as to the actual prevalence and seriousness of such conditions is important, but the facts are already sufficiently known and acutely enough felt to justify study of remedial measures. Lumber is the principal commodity from the forest and presents the most aggravated marketing problems. Consequently major attention at this point will be devoted to that product, although many of the requirements with respect to lumber apply with equal force to other forest products.

TRANSPORTATION

Forest products are at a distinct disadvantage in the struggle for lowered costs because of the heavy transportation factor. Lumber carries a railroad freight cost averaging $283 for every $1,000 value, compared with $263 for cement, $198 for common brick, $79 for iron and steel, and $58 for wall board. In the decade 1914–1924 the average length of haul from mill to place of use increased from 360 miles to 725 as the nearer sources of supply approached exhaustion.

Improvement in transportation costs lies along three lines: (1) Adjustments in freight rates, (2) elimination of unnecessary cross-hauling, and (3) putting into maximum production those forest areas closest to centers of use.

The principal action thus far to cope with transportation costs has been that taken by the forest industries in securing more favorable rates from the railroads and in utilizing the water route via the Panama Canal. Railroad rates are, of course, subject to further change. Existing freight rates for commodities in general are the resultant of slow adjustments over long periods of years as between competing industries, sections, and public carriers. Lumber tariffs have probably not reached the same degree of stability that exists in

the case of other commodities, because of the shifting centers of lumber production. Active study may disclose that it is to the advantage of both railroads and industry as well as to the public served to bring about changes in the rate structure for lumber in particular. However, revisions large enough substantially to change the relation between competitive commodities seem unlikely. The possibility of reduced transportation costs by means of inland waterways, such as the Lakes-to-Gulf route, warrants careful scrutiny by timberland operators.

The elimination of the hidden but nevertheless heavy burden arising from crosshauling is a factor to be taken into account. The National Lumber Manufacturers' Association estimates that, of the annual freight bill for lumber of half a billion dollars, one tenth is for crosshauling that is unnecessary. Few deliberate steps have been taken actually to cope with the situation. It is axiomatic that to realize the advantages of home markets the standards of efficiency in production methods must be kept abreast of those in the regions most aggressive in reaching out for distant markets. The concentration of sales and promotion activities in those zones nearest to source of supply is a logical thing for the forest industries to work out, as systematically and energetically as possible. As each producing region studies its full possibilities, considerable reduction in crosshauling should follow.

Important as reductions in freight rates and crosshauling are, basic improvement can come only as the supply is brought closer to the centers of consumption. Much land in the East from which timber was cut in the earliest days is still forest land, but the growing stock on these forests close to centers of population has not been adequately maintained. Nevertheless, even the diminished output that has continued in this region has kept down the transportation factor to some extent.

The bulk of high-grade lumber must necessarily be supplied by the West until eastern and southern forests are thoroughly rehabilitated. Meanwhile the large uses for lumber, at present at least, are for sheathing, framing, concrete forms, boxes and crating—uses served by such material as is now being produced in substantial quantities from second-growth forests of the eastern and southern region and can be relatively easily supplied in the future. Certain measures that may confidently be anticipated to improve the competitive status of lumber, such as treatments against decay, insects, fire, and shrinkage, are as well met by second growth as by virgin growth. Also, for many of the industrial uses of lumber, the increasing trend toward cutting of the parts direct from the log at the point of production rather than from lumber at the factory removes many of the present objections to smaller second growth.

It is the production of the common grades of lumber from the East and South that keeps the price of western lumber down, and of the high grades from the West that keeps the price of eastern lumber down. This competition is at the expense of "skinning" the growing stock in the East and the leaving of tremendous waste in the woods in the West. Building up the older age classes in the forests in the eastern half of the country is essential in the interest of eventual lower costs. The owners of eastern timberlands have difficulty in comprehending this fact in the face of continued shipment of cheap western timber. The need for measures looking to the wider acceptance of the

facts is obvious, but reliance on education as now conceived is not very promising.

Holding back the cutting of growing stock to safeguard future productivity means, it is true, a higher average transportation cost for the immediate present as a larger percentage of lumber comes from the West. The loss in competitive position of lumber products that might arise from this cause should be resisted by the development of improved and economical timber products such as mill-fabricated items, plywood for sheathing, concrete forms, siding, and the like.

From the single standpoint of minimum transportation costs it is obvious that the North Atlantic States, the Lake and Central States, and the South, by their greater accessibility to the chief centers of use, warrant first attention in intensified forest management.

SELECTIVE LOGGING AND SUSTAINED YIELD

Markets are being supplied with lumber from private holdings at higher production cost and of lower average grade than would be the case if selective logging were generally practiced. It has been convincingly established in every producing region that the smaller timber is handled at a loss in most lumber operations. In southern pine, for example, the small trees are often cut at a loss of approximately $10 per thousand board feet, which adds to the price at which the larger timber must be sold to yield a profit.

Three important steps toward lowered costs become possible as the principle of selective logging and sustained yield is put into effect: (1) Elimination of material that fails to pay its way; (2) saving the investment in plant, mill town, and forest land that in the case of migratory operation must be charged off in the price of the products at a rate as high as $2.50 per M for typical southern mills; (3) realization of lower raw-material costs by making possible the stable operation of integrated secondary industries. The last point is considered in more detail under the next heading.

From an economic point of view, timber owners can now hardly afford to neglect the practice of selective logging wherever the character of the timber permits. But often important obstacles to its practice or privately owned lands remain to be overcome. Further discussion of measures that are required to realize the benefits of selective logging and sustained yield occurs elsewhere in this report. The fact that needs to be borne in mind at this point is that substantial reductions in current production costs are made possible by selective logging.

INTEGRATION OF INDUSTRIES

Integration of the sawmill with pulping plants, veneer and dimension mills, and the like, is a major requirement for lowered costs. For the most part, forest industries have been specialized, and each has made its independent draft on the raw material supply. The resulting wastes are proverbial. However, enough has been accomplished thus far by industrial integration to point out possibilities of improvement. Within recent years the pulp industry on the West coast has come to operate to a large extent on the waste from logging and sawmilling operations, with the result that pulp mills 2,000 miles from Chicago can compete with those 200 miles away. In the Lake States,

in a few instances, the full run of the forest is sorted under an integrated scheme of operation according to its suitability for the sawmill, dimension plant, veneer mill, and distillation plant; or, in other forest types, for the pulp mill, sawmill, box factory, and specialty plants.

In certain operations in the southern pine region, integration of sawmills, pulp mills, and veneer and plywood plants has been accomplished. Large holdings that are being developed primarily for pulpwood contain saw timber or medium-sized trees that will grow to saw timber size before the stands are cut for pulping. The plans call for cutting the high-quality logs into timber products to defray a large part of the cost of stumpage, instead of pulping all material indiscriminately. In Sweden the close integration of lumber and pulp industries results in close and flexible utilization in accord with market conditions, a diversification of product, and maximum value from the raw material. Basically such developments are sound and, other things being equal, are the way to minimum costs.

Integration is not necessarily confined to large plants and heavy capital investments. Partial integration already exists in the small-scale operations of sawmill, turning plant, and novelty factory in New England and of tie mill, flooring plant, and spoke and handle factory in the Middle West. For the most satisfactory functioning, however, we must look to adequately financed and fairly large units.

It has been through integration of sawmill and pulpmill operation that the greatest advances have been made thus far. It is between these units that great progress in the immediate future may be looked for in the virgin forests of the West and in the second-growth forests of the South, although there are limits as to the part that the lulp mill can play. There are good grounds for anticipating also a much wider integration, on a smaller investment basis, between plywood manufacture and lumber production in regions where virgin timber is still readily available and between pulpwood, naval stores, and timber products in the Southeast.

It is not to be assumed, of course, that all production from the forest will be on an integrated, diversified basis. Lumbering on a small scale lends itself to individual effort, particularly in regions where the timber supply is scattered, and account must be taken of the fact that small independent operations will always play a part in the ultization and marketing situation. Integration in this country has not progressed to the point where it is more than an indication of the part that it must play if large-scale markets for forest products are to be maintained. The way to the realization of its benefits must be kept open through continuing research and organizing and management effort.

PRODUCTION FROM SMALL TIMBER HOLDINGS

Portable sawmills share responsibility to a greater degree than large ones for putting out substandard products which undermine confidence in lumber. By stressing cheapness, small mills have played strongly into the hands of those elements in the building trade that have engaged in speculative building and shoddy construction. So unskillfully has the product been marketed that it has constantly disturbed the equilibrium of the entire price structure. A large proportion of the remaining saw timber, particularly in the eastern half of the country, is in farm woodlands for much of which the small sawmill is the strongest bidder in sight.

Fortunately, there is now a strong trend toward improved quality from the small mills, so far as accuracy of manufacture is concerned. It is becoming recognized that small mills properly designed and operated and cutting good timber can produce good lumber. In a growing number of instances capable business men directly or indirectly are managing the operation of groups of small mills. But it is the existence of large numbers of both good mills and poor mills that brings up for serious consideration the small mill as a factor in future marketing developments.

Small mills have always shown a marked sensitiveness to business conditions. Their credit is generally limited, and, while they increase rapidly and their added production tends to hold down prices on the ascending side of the business cycle, on the descending side they reach their credit limit quickly and drop out. On the assumption that flexibility of quantity and stability of price are desirable, limited credit may here seem to be beneficial. On the other hand, in strengthening the competitive drive in the lumber market, limited credit appears as a detriment by forcing a glut of products on the market. Measures for strengthening the credit of small sawmills have been discussed by the industry. It is important to realize, however, that measures that do not also work to the benefit of the owner of the standing timber will merely foster the increase in output of the least efficient mills.

The key position in adjusting small-mill production to requirements of orderly manufacture and marketing is held by concentration plants buying rough lumber from these local units. In the case of softwoods, practically all the lumber produced by portable mills is finally seasoned, surfaced, graded, and put on the general market by concentration plants. In hardwoods, which are commonly sold rough, the output is but infrequently graded or marketed through comparable central units. The nucleus around which improvements can be put into effect are thus present in the one case but lacking in the other. The small-dimension-stock plant appears as the most logical unit to take the place among portable hardwood mills that the concentration plant now holds with softwoods. Fundamentally, control must be hinged upon demonstrating to the concentration units the advantages to them of improved operating practices.

A measure of the effectiveness of counsel, demonstration, and education will be available from what the Southern Pine Association is now attempting among small-mill operations in its territory. The program of this organization is more systematic and extensive than any other thus far undertaken. The aim is to aid the small mills in their weakest spots with higher standards of manufacture, seasoning, grading, and, particularly, marketing. Success in this industrial program will indicate that similar measures can be depended on for small mills in other producing regions; failure would suggest that control must be worked out by more drastic measures.

If the small mill continues to hold its present position, the best markets for lumber cannot be protected in the future unless marked improvements are put into effect.

IMPROVEMENT OF PRODUCTION

Much dissatisfaction with lumber is due to shortcomings that are under the control of the manufacturer and that technical research

has already shown how to correct. There are three lines of improvement entirely beyond the experimental stage that are clearly capable of putting production on a sounder basis: (1) Moisture content control through better seasoning; (2) improved selection and grading; (3) making decay-resistant lumber generally available.

The shrinking of lumber after being built into a finished product provides one of the most prolific sources of dissatisfaction with the performance of wood. In one part of the country the point has been reached where a group of building and loan associations refuse to finance homes constructed of a species that is customarily shipped green and undersize into that region. The remedy—to use only seasoned wood—is clear but too frequently ignored by producers who, more than the other groups involved, have a controlling hand in the matter.

The moisture content at which lumber for different building purposes is stabilized with reference to shrinkage is known. Commercial shipments of building lumber as a rule deviate widely from the plain requirements. Practical methods to measure the moisture content and drying equipment to produce uniform seasoning are readily available on the market. The necessary improvements need only to be put into effect. For its own protection, the lumber industry should see to it that seasoned lumber is made more practical to obtain and that the use of unseasoned lumber is limited to places where its subsequent seasoning and shrinkage will not be harmful.

The present principles of grading, so far as the bulk of the lumber output is concerned, are essentially those of years ago, when competition between building materials was less keen than at present. Despite the degree of progress registered in the adoption of American Lumber Standards, the prospective buyer of lumber is now faced with a bewildering array of species, specifications, and conflicting claims. Furthermore, the lumber grades bearing the same name in different species often differ widely in quality. Confused and skeptical, the prospect often turns to other materials easier to specify and offering more satisfactory guarantees of quality. Architects, with whom rests to a large degree the choice between wood and other materials, have strongly criticized the present lumber grading system. While leaders in the lumber industry recognize this dangerous situation and are taking steps to remedy it, market requirements call for prompter action. The Timber Conservation Board has recommended something in the nature of a "pure food law" for lumber that would require shipments of lumber and timber in interstate commerce to be graded and indentified in accordance with publicly recognized standards of grading and inspection. The desirability of careful selection of species and grades for the more exacting uses can hardly be overemphasized.

Resistance to decay and insects is a property in great demand for material that must be used in damp places, in contact with the ground, or wherever moisture tends to accumulate in the wood. While resistance can be provided to some extent from the heartwood of naturally durable species, it must frequently be provided artificially by impregnation with suitable preservatives. Properly preserved timber, with few exceptions, is not easily obtained by the rank and file of lumber users. Attempts are being made in several parts of the country to make suitably treated timber available through retail lumber yards.

They will no doubt succeed in the course of time, but they need to be expanded and strengthened. Much care is required to assure that only well-treated material is provided.

MERCHANDISING

Lumber, the principal forest product, has thus far largely "sold itself." Several factors, unnecessary to enumerate, have contributed in the past to a strong position for lumber and obviated the necessity of strongly organized merchandising effort. But conditions of the past no longer prevail. Lumber is contesting with other materials for practically all its markets, and there is now imperative need for promotional effort in the broad sense. Until up-to-date merchandising has had a chance to show its full effects, previsions of permanently inadequate markets lack realism from the economic point of view.

In the long run, merchandising effort must be based, first, on sound foundations of quality and technical control, as discussed in preceding paragraphs, and, second, upon coordinated sales policies that insure to the consumer material of the type and quality to meet his particular requirements.

The groundwork has already been laid in American Lumber Standards for fundamental improvement that is well within the hands of the trade to put into effect, either by itself or with the aid of public agencies in certain respects. Standard grading and grade marking are measures that are particularly needed as a guaranty of quality in which the consumer can put his confidence. It is even more essential that the lumber industry itself take cognizance of the species and the grades and qualities within a species that are inherently suitable and justify promotion for a given use.

Organized demonstrational and educational effort must be applied to focus attention of the buying public upon the merits of wood properly prepared and selected, and how to avoid dissatisfaction in its use. Mistakes of design and construction to be avoided—as, for example, the use of untreated wood in damp locations, or lack of measures for fire-resistance—must be made plain to the users.

Many prejudices against lumber will disappear as the producers take a firmer grasp of quality control and preparation of the product. Others will be removed only by educational work. For the technical buyer, especially, data regarding the properties of wood and its use in engineering structures must be made available in manuals and textbooks comparable to those available to him in the use of other materials.

The merchandising that will be effective in holding and extending markets for lumber products involves not only attention to the major established outlets but also recognition of new deeds and latent wants, and provision of ways to meet them through the use of lumber. For example, good roads and the automobile (still too largely unhoused) open to the masses opportunities for recreation, which in turn offer new possibilities for lumber if satisfactory cottages and camps can be made available on a low-cost basis. Only active merchandising can develop such possibilities. The widespread desire of home owners for wood paneling and finish presents another challenge and opportunity that only effective merchandising can meet. City dwellers are still inadequately housed, and farms are getting but a fraction of the buildings and repairs that they need.

Only when lumber and other wood products are presented to the consuming public in the best possible condition, with adequate demonstration of their merits, with a catering to unsatisfied desires, and in accord with the findings of research, will it be time to consider whether the national market for such products is indeed "inadequate".

RESEARCH IN FOREST PRODUCTS

It is submitted here that scientific research in wood and wood products, steadily prosecuted and the results applied, can be followed up to large practical gains in the production and marketing of the forest yield—in the lowering of costs, in insuring greater satisfaction to the consumer in the service of the product, and in opening the way to new products and enlarged uses.

Other products have felt its influence; in fact, scientific research is the foundation and pattern of the industrial age. Through research, products have been refined and diversified, new materials developed, mass production in old and new lines made possible with consequent cost reductions, and mass consumption awakened beyond the conception of past generations. Most of our modern industries—steel, aluminum, and other nonferrous metals, alloys, glass, ceramics, refractories, petroleum, foodstuffs, machinery, textiles, plastics, cement, chemicals, electricity, etc.—have come to depend on the research of the scientists and the technician for their continued progress and the expansion of their markets.

With iron and steel, for instance, it was primarily the lowering of production costs through the development of the Bessemer process, followed later by the development of the open-hearth process, which enabled structural steel to be marketed at prices which have resulted in the use of millions of tons. It was the microscopic and phase-rule studies of the coarser and finer crystal structure of steel that enabled research to correlate crystal structure with strength properties, and that have guided the development of steels of such innumerable different properties as manganese steel, which is hard and tough and used in grinding machinery; tungsten steel, which is self-hardening; vanadium steel, which withstands shocks better than other steel; chrome steel, indispensable in cutting tools; nickel steel, which resists corrosion; duriron, which resists the attack of acids; and stainless steel, containing chromium, which retains a mirrorlike surface indefinitely. Without these successful efforts to lighten, strengthen, and cheapen the material, our sleek and satisfactory automobiles of today would still be the lumbering tractorlike vehicles of the early nineties, and our rapid-fashioning machinery would be impossible.

Aluminum, industrially speaking, is a comparatively "new" metal. For years it was known that it was the most extensively distributed of the metals, making up about 7 percent of the earth's crust. It only awaited a means for obtaining it cheaply in metallic form from the clays and rocks in which it occurs. One hundred years ago it sold for $160 a pound. Research had brought down this cost by successive stages to $4 a pound in 1886, at which time the present electrolytic process was discovered. This discovery finally placed aluminum production on a remunerative commercial basis and was responsible for an output of more than half a billion pounds of

the metal in 1928. Today, through continued intensive research, the cost has been further reduced and the quality and strength have been improved to such an extent that aluminum and its alloys are already competing with steel in important structural uses, while wider markets are being opened up in paints, coatings, welding, sheet uses, and machinery.

Research in glass composition and manufacture has brought about three revolutionary developments in the last 20 years—the production of Pyrex glass, improved optical glass, and shatter-proof glass—all to the great advantage of American industry. The present rayon industry, with production values at $150,000,000 in 1929, is a direct outgrowth of research carried out with the purpose of duplicating the product of the silkworm. The development of cellulose lacquers has opened up an entirely new chapter in automobile and furniture finishes. To cellophane, another new research product in the cellulose group, has been awarded the credit for a considerable share of the financial success of one large corporation during the depression. Research in the preservation and refrigeration of foods has practically "reversed the seasons" and has been the foundation of enormous industrial developments of late years. Long and patient research in the fixation of nitrogen has at last made it possible to extract from the air the most essential fertilizing element for our soils.

Over against the large body of American industries that have enjoyed significant progress and profit through research, the majority of wood industries seem to occupy a place apart. Scientific standards have rarely been the controlling factor in logging, for instance, or in the production and use of lumber. The use of wood is guided less by modern technology and more by traditional business practice and artisans' rules. It is a fair assumption that, in the strenuous competition of industries for present-day markets, neglect of fundamental and applied research on a given material will impose a severe handicap on its use. Only in certain fields of chemical utilization—such as pulp and paper, rayon, and plywood—has wood maintained or improved its position as a basic material, and it is in these particular fields that research has been most actively supported and applied.

Along with the development of scientific and technological research, there must be increasing attention to all of the economic factors involved. Without such information, authentic in source and comprehensive in scope, neither the selection of specific research projects nor the effective application of the results can be guided most soundly. As an example, in the field of pulp and paper research the proper choice of species for first study and the adoption by industry of the results, if successful, both depend on knowledge of the cost and future supply of these and competitive species, as well as knowledge of production costs, transportation costs, and their relation to and effects upon competing production. Problems of this nature are so important and complex that they must be recognized and adequate research organized for their solution. To be most effective, such research should be closely coordinated with the scientific and technological phases of the work.

BETTER USE OF WOOD IN CONSTRUCTION AND FABRICATION

Research must show the way to radical improvements in wood construction. The convenience, low cost, and other advantages of wood must be combined with simplified, efficient, and cheap design and erection, and better preparation and maintenance of the material, to produce more durable and economical structures. Wood has lost ground competitively because of insufficient technical progress in its use. Since more than 60 percent of the lumber produced in the United States is used in the construction of buildings, it is especially important that this market be retained and expanded. Intensive research vigorously prosecuted offers the only practical way to keep wood abreast of the continuous technical progress being made by its competitors and thus to avoid unnecessary substitution of competitive materials for wood.

UNIT CONSTRUCTION

Wooden houses cost too much. Present designs and methods of building coupled with the normal tendency toward higher wages and shorter hours have reacted to discourage building. The obvious answer is mass production of wood units that can be assembled quickly and inexpensively, in line with similar developments that are occurring in steel and concrete housing. The progress that has been made thus far is entirely inadequate.

Research therefore has an urgent practical objective in seeking to develop practical forms of wooden-unit construction for dwellings and larger buildings. Full-scale tests of special forms of wall, floor, and roof units should be made. One type of material that offers itself for use in large units is plywood. Ready-made plywood wall sections embodying self-contained insulation may prove an economical and satisfactory replacement for the present composite wall of wood and plaster. The development of such untis involves several phases of research—practical and efficient design; tests for strength and weather resistance; the production of a cheap, permanent, water-resistant glue; and of sightly, weather-tight joints. Another possibility is the development of built-up lumber units of an interlocking type. In any kind of unit construction, the design of the structure as a whole requires adequate architectural study to insure acceptable variety, appearance, and convenience.

ENGINEERING RESEARCH

Great improvements in building construction can be made without waiting for the development of mass production. Built-up wooden columns and glued laminated arches and beams should replace much expensive solid timber. They permit better selection of the wood for quality, favor refinement in design, conserve the large sizes of timber, and make possible the utilization of smaller, cheaper units of lumber. Laminated wooden arches are especially suitable in the construction of halls, hangars, and other buildings of large open span and are finding extended use in Europe. They need thorough testing and adaptation to American use. The Forest Products Laboratory has investigated the problem of the built-up column and determined a

form of construction that is cheaper and approximates the strength of solid timber. At present, effort is directed toward the production of a glued laminated beam that will require high-grade lumber only at the top and bottom, where stresses are highest, and can utilize low grade and short-length material to fill in. Accomplishment of this objective will make available beams of better and more uniform quality and will lead to closer design, lower costs, and increased markets for low grades of lumber.

Conventional joints and fastenings in heavy timber construction are inefficient. Modern engineering efficiency and high costs of material will no longer permit lavish use of material to obtain strength and rigidity. Methods must be improved so that joints of greater durability and reliability can be made at less cost and with more efficient utilization of the strength of the wood. Marked progress has recently been made in determining strength values for nailed and bolted joints and correcting previous handbook figures that varied as much as 600 percent. Further work for research lies in determining the holding power of screws in different woods and in developing metal jointings in the nature of dowels or keys to supplement bolt bearings in structural members. Experience abroad indicates that wood adequately jointed may successfully contest the market in large and increasingly important uses, such as radio masts, transmission-line towers, and higheay bridges.

The basic design factors of wood structural members are not sufficiently known. Timber structural design at present is a process of approximation. In the average wooden structure there are parts vastly oversized for the strength required and others inadequate to resist racking, bending, compression, and other live-load effects. Since we must consider three axial directions in wood there are 3 Young's moduli, 3 shear moduli, and 6 Poisson's ratios, or 12 elastic constants to be taken into account. To compute rightly the elastic behavior of wooden members under stresses requires experimental determinations and the development of engineering formulas far in advance of those now available.

An example of the practical benefits to be gained today by a revaluation of design factors in wood members is the more satisfactory and economical design of bridge beams in shear advocated by the Forest Products Laboratory and recently adopted by engineering professional bodies. Acceptance of the new rule means that railway and highway bridge stringers can be sized to meet actual shearing stresses rather than the stress figures formerly used, which often exaggerated the actual condition by 50 to 100 percent. Wooden bridge design has been made more exact and the sizes of beams have been brought more closely within the range of commercial production, so that there is less reason to turn to more expensive material.

Greater attention must be paid to designing wooden structures for appearance. The very great economy of treated wood for highway bridges and similar purposes is frequently ignored because other structural materials are believed to produce more pleasing or imposing structures. Introducing art into wood-bridge design will serve the double purpose of expanding the markets for wood and getting larger returns on public expenditures.

FIRE RETARDANTS

The development of a complete, inexpensive fire-resistant treatment would do much to regain immense markets for wood that are now closed. Building code and underwriters' requirements limit the use of wood for exterior walls in residential, industrial, and commercial buildings in urban areas. To a less extent wood framing is handicapped in competition with less combustible materials. Fire-resistant treatments are now available but too expensive for general use. Recent studies encourage hope for marked improvement. Several highly effective chemicals are known, and combinations of certain chemicals give promise of even better results in respect to economy, noncorrosive effect, permanance, and other advantages. A combined treatment embodying fire resistance, decay and insect resistance, and reduction of shrinking and swelling properties is a major objective that may ultimately be attained.

PREVENTION OF SHRINKAGE

A successful treatment to prevent shrinking and swelling would do more than any other single accomplishment to simplify and cheapen the use of wood in doors, sash, trim, furniture, floors, and a host of other wood products. It would also result in so much better service and satisfaction that the popularity of wood for these purposes would increase, and expanding markets would inevitably result. Chemicals have already been found that reduce the shringage as much as 90 percent, but the wood so treated shows a decided tendency to become wet and drip in a very damp atmosphere. The problem is to find new chemicals of high effectiveness that are free from this and other disqualifying objections or to find ways to change the injected material to nonhygroscopic forms. Increasing knowledge promises that the desired result is by no means impossible.

PREVENTION OF DECAY

Decay is a major menace to the permanence of wooden structures. Unprotected wood in service is being lost through premature decay at a rate comparable in magnitude only with the destruction caused by forest fires. Research and experience have shown that decay prevention is possible by the proper use of preservatives and often by improvements in design and construction to avoid the conditions that favor decay. Railroads and other public utilities annually treat millions of cubic feet of ties, poles, piling, construction timber and miscellaneous lumber with creosote, zinc chloride, and other preservatives. The serviceable life of the wood is increased two to ten times, and enormous financial savings result. Wood is thus enabled to retain large markets which would be closed to it if only the relatively short life of untreated wood under decay-producing conditions were attainable. The sphere of research in the continued development of wood preservatives and treating processes is very large, necessitating the collaboration of the engineer, the physicist, the chemist, the entomologist, the plant pathologist, and the toxicologist.

The desirability of lower treating costs is obvious. The danger of reducing the strength or causing unsightly defects during treatment is very real. The total recognized loss in value from this source amounts

to a large sum annually. The unrecognized losses undoubtedly are still greater. Refinements in treating technic resulting from research and the development of milder but effective treating schedules can eventually reduce these losses to an insignificant amount. These same improvements can also decrease the very appreciable losses that result from inadequate or ineffective treatments and can lengthen the average life obtainable from treated timber.

Adequately treated timber is not readily available to the average small consumer. The undesirably high cost of thoroughly treated timber and the lack of adequate distribution machinery have limited its use principally to consumers who can purchase in large quantities. Greatly expanded markets await the developments that will overcome this obstacle.

A special need for research is in the development of effective but inexpensive decay-resistant and insect-proofing treatments of lumber for dwellings and general building construction. The preservatives must be substantially odorless and colorless, satisfactorily paintable, cheap, permanent, simple in application, and harmless to man. The definite progress that has been made in this direction must be greatly extended. Public demand is already insistent.

Proper design and construction can eliminate much of the decay and insect attack in dwellings that is now costing home owners large sums of money. Investigations have already shown that contact of wood with the ground must be avoided, adequate ventilation provided around all wood near the ground, and all practical precautions taken to keep the wood dry. While the application of present methods of control will aid materially, a survey of existing conditions followed by an evaluation of the factors affecting decay and insect damage is badly needed to indicate the most efficient methods of eliminating building losses that are all too prevalent at present.

PAINTING AND MOISTUREPROOFING

The painting of houses and other woodwork constitutes an expensive item of maintenance that must be reduced. It is often the factor that determines the choice of other building materials in preference to wood. The Forest Products Laboratory has shown why the painting problem is more serious with some woods than with others. The general remedy, however, is not yet at hand, because our most abundant construction woods are the ones hardest to keep painted. It seems necessary to find paint vehicles more permanent than any now known. In the whole storehouse of nature and modern science some combination of pigment and vehicle must be possible that will cling to wood like part of its own substance and furnish the artisan with a material he has never dared hope for. If such a combination is possible it remains for chemical research to find it.

There is a constant demand for moistureproof coatings for wood. No simple coating process has yet been found that is more than about 75 percent effective in preventing moisture changes, and this degree of effectiveness gradually decreases upon continued use or exposure. Highly effective and durable coatings would find extensive use and would greatly improve the performance of wood in such products as boats, airplanes, furniture, and a wide variety of factory products.

GLUING

The development of a cheap glue that will be as strong, as reliable, and as permanent as the wood itself will enormously expand the opportunities in the economical and profitable use of wood. The glues thus far developed by research from blood, animal tissue, casein, vegetable proteins, and phenolic resins are excellent in many ways and a great improvement over those available in the past. As yet, however, they all fall short of the ideal in several respects. Today the woodworker takes great pains to dry his lumber carefully and to bring it to the proper moisture content for gluing with minimum trouble. Then, with most of the glues available, much of this tedious work is undone by putting back into the wood a large amount of water along with the glue. Not only must time be taken to dry the wood again, but many perplexing difficulties of woodworking arise from the sweeling and shrinking of fine surfaces and carefully made glue joints owing to glue moisture changes. Glues that contain no water are being developed. The active aid of research is needed to make them cheaper, better, and more generally adaptable to all kinds of gluing.

DESIGN OF FABRICATED PRODUCTS

The most efficient design of shipping containers is handicapped because of lack of specific knowledge of the hazards of transportation. The work of the Forest Products Laboratory in the design of wooden boxes and crates has been largely instrumental in bringing American containers and packing methods from recognized inferiority to recognized superiority and in reducing freight damage claims by millions of dollars annually. But this is not sufficient. Further study and surveys are necessary to determine the nature and causes of damage to containers and their contents in both domestic and export shipment and to translate the needs of shippers into terms of wood properties. The importance of this work is measured by the present consumption of wood in shipping containers, which takes one sixth of our lumber cut and a large and increasing proportion of our pulp production.

In the same way as for boxes and crates, the available data on wood properties should be applied to the fundamental design problems of other fabricated wood products. To almost every manufacturing industry using wood, a more perfect knowledge of the material and its properties and better means of turning its properties to account in service would conduce to improved wood products and markets. In the auto-body industry, for example, keener selection and evaluation of wood for posts, sills, and rails would avoid defects of weakness and brashness now sometimes encountered, would perhaps extend the range of usable species, and would retain the elastic riding qualities of wood coachwork, while suitable preservative treatment would eliminate the decay hazard, and better gluing and jointing would guarantee strength and long service life. Wood is and has been used in thousands of manufactures, from barrel staves to Pullman interiors, but its supremacy for these uses is by no means permanent or assured. To maintain or increase the market for wood obviously calls for more competent technical knowledge of the material and better use of that knowledge by the designer.

MORE MARKETABLE PRODUCTS AND LOWER COSTS

Like all other materials, primary wood products are susceptible to improvement through research in form, properties, and costs. Assets capable of withstanding strong competition lie latent in the present forms in which wood is marketed—high strength per unit of weight, integrally bonded structure, impregnating qualities, nonconductivity, working and finishing qualities and chemical derivatives, all in supplies that are continuously renewable. But other materials in recent years have established standards of service which necessitate changes in wood products.

Improvement, in order to yield maximum benefit, must be based first of all on better compliance with the requirements of the consuming market. Refinement of product with lowered cost is unquestionably the outstanding consumer demand and the largest factor controlling the future markets for wood. Refinement beyond an elementary stage involves also diversification of product to deal with the inherent variability in the wood itself and in the trees and forests from which it is cut, and diversity in any adequate degree involves the integration of producing units. The main lines through which improvement is to be worked out, discussed under a previous heading, call for factual information, some of which is already at hand, but much of which still is to be obtained. Further research in this field consists chiefly in working out the means of applying in practice the results from more fundamental scientific knowledge.

THE FORM OF PRODUCT

Research has advanced the use of materials competing with wood through the development of sheet or fabricated units of large size, high strength, and light weight. The advantages from the standpoint of both structural and architectural design and installation costs have given rise to a consumer demand that is permanent and irresistible. Forest products have given partial recognition to such demand, but the possibilities have only been touched and are limited only by the amount of research that is devoted to them. The possibilities and actual developments in pulp and cellulose products in this field are well recognized. In the field of plastic and molded products there has come to partial realization a method whereby the cellulose and lignin of wood are combined with aldehydes to form a product which can be molded under pressure to give a hard material very resistant to moisture change and with no tendency to shrink or swell.

Since the lignin, cellulose, and aldehyde can all be obtained from the wood, the process may be considered as self-contained, and only the small amount of mineral acid needed to effect the reaction need be supplied from other materials. If the results thus far obtained are substantiated by further work, large-scale production of new products from what is now waste material is made possible. Additional possibilities lie in the discovery of a satisfactory binder for consolidating fine particles of wood and also in the glutinizing of the surfaces of wood particles to produce adhesion when pressure is applied.

Plywood as a major wood product commands attention on account of the possibilities it holds in units of large size, high strength, and lightweight ratios, in low cost treatments to guard against fire,

decay, and shrinkage, and in full utilization of the log. Plywood already is changing from a product for decorative purposes to one that has wide possiblities in the structural and fabrication fields. Great significance lies in the fact that its consumption, like that of of pulp, paper, and cellulose, is rapidly increasing, whereas that of other forest products has been on the decline. The development of a good water-resistant glue and of commercially practicable methods of using it have put plywood into entirely new uses, as in concrete forms and wall and floor construction, in which lumber has been losing markets to other materials.

The present conception is that only large-size clear logs can be used economically for the manufacture of plywood. Research is needed to determine whether relatively poor and small logs may not also be usable through the development of improved cutting methods and machines. Methods may be found for cutting veneer from logs now suitable only for lumber so as to make the saving in kerf compensate for the loss in speed of cutting.

Even failing the development of radically improved cutting methods, further attention to veneer production is almost certain to bring to light the practicability of using in structural plywood timber of lower quality than is now used.

Dimension stock has been proved by factory studies and actual practice to meet the requirements of many of the wood-using industries better than lumber. These facts have led to the shifting of machining operations from the factory in the distant city to the sawmill near the supply of timber. This has been particularly the case in the auto-body industry and to a less extent in the production of furniture and sash and doors. The saving in freight on waste and the better advantage in the cutting of the material from the log have proved to be important factors in reduction of costs to the user. It has been found from production studies in the Lake States that the use of improved operating methods and specially designed machines result in a higher material and monetary return from second-quality timber for mill-cut dimension stock than cutting the same quality or even a better quality of material into lumber. The further development of methods for producing high-quality dimension stock, including sawing, seasoning, and bundling, is required. Modifications need to be worked out not only to meet the requirements of consumers but to apply to different classes of timber and size and character of holdings. The need is particularly urgent to meet conditions in New England, because dimension stock production affords the key to the management of hardwood timberlands in that region and to the supplying of an important market with home-grown material of good quality. Especially important also is the development of dimension-producing units to serve as concentration plants for the output of hardwoods from farm woodlots in the North, South, and East.

SELECTION AND GRADING

In addition to the new and improved forms of wood that should be developed to meet modern demands, lumber itself through various improvements near at hand or in prospect can become almost a different product and thereby strengthen its own position both in cost and in quality.

In the case of a highly variable material such as wood, it is quite obvious that selection is the key to refinement, but in the case of lumber the basis of selection has never been adequately developed. Use requirements are met at present largely on the basis of the species and rather arbitrary grades determined by the occurrence of knots and the like. But a species possessiong high average shock-resisting properties, for example, has been proved by tests to yield substantial proportions of material no higher in shock resistance than species of much lower rating. The same applies to all the other properties of wood. For any assurance of getting qualities required, the consumer has had to rely heavily on the reputation of the supplier and of the locality of growth. In the noncompetitive era for lumber such practice may have sufficed, but it can hardly be expected to serve for the future. Research has established that the specific gravity test, which can be readily applied, is a good working index of many strength properties and a sound basis for classifying material of any species into high, low, and intermediate groups. New values will be realized as wood of low density is sent to those that want low density and wood of high density to those that want high density, rather than a mixture of all kinds to all users.

Experiments are under way to develop a strictly portable instrument for getting an instantaneous measure of the hardness of wood as an index of specific gravity. Such an instrument in the hands of a commercial grader will pave the way for radical improvements in selection to meet use requirements. Within the last 2 years an instantaneous tester for moisture content has been developed from fundamental work on the physics of wood. This instrument, now being sold by several makers, has led to marked improvements in providing consumers with properly seasoned lumber. Its further adaptation, together with a fuller development of moisture-content specifications, holds promise of removing many complaints against lumber.

Other reliable commercial tests are needed to measure and select for decay resistance, freedom from swelling and shrinking tendencies, toughness, resistance to abrasion, and many more properties in which wood exhibits a great variation. Aside from selective tests, science needs to provide ways of evaluating all the properties of wood so as to suit it more exactly to the purposes intended. The facts recently established as to the characteristic defects of the important softwood species need to be taken into account in the fuller development of use grades.

SEASONING

Poor seasoning has been the cause of much dissatisfaction with lumber and has resulted in heavy loss of markets. Great advance in recent years has been made as a result of research, but many problems still remain to be solved before seasoning is put on a basis that permits lumber to compete to its best advantage. Both artificial seasoning in dry kilns and natural seasoning in the open air are involved.

The need for kiln-drying arises from two main requirements. One is economic—to reduce freight costs, to reduce the quantities of lumber held and hence the investment, to reduce seasoning losses, and to fill orders on short notice. The other is physical—the necessity

of having lumber drier than can be obtained by air seasoning in regions where the products are used in heated houses. For such regions and purposes lumber must of necessity be kiln-dried even if it is first air-dried.

Comparatively large and unnecessary losses are still incurred in current kiln-drying processes. Investigations to determine the causes and remedies for such losses have been under way for a number of years. A reasonably satisfactory empirical understanding of the manner in which seasoning defects are brought about and of ways in which they can be avoided or remedied has been obtained. The general effect of variations in the controllable conditions is sufficiently understood to make it possible to draw up reasonably satisfactory drying schedules. For the more common lumber products such schedules have been developed in the Forest Service for about 50 important American species, and additional schedules are being worked out.

An important cause of present poor drying practice lies in inadequate kilns and equipment. Research on drying schedules has carried with it the development of several new types of kilns and the perfection of control apparatus which have become standard equipment in the industry. As the drying of special forms, shapes, and sizes becomes more common, corresponding progress in drying equipment will have to follow.

A number of important seasoning problems still remain unsolved. Most of the work hitherto has had to do with lumber and other comparatively thin material. But ties and timbers of most species suffer excessive degrade during seasoning, with a corresponding loss in value. Many special sizes and shapes of dimension stock of various species still require study before satisfactory drying methods can be had. Certain groups of species cannot be satisfactorily seasoned by any known methods. Among these are southern swamp oaks and some of the other southern hardwoods. It becomes necessary, therefore, to develop some new and radically different method of seasoning which will permit this material to be seasoned in a reasonably satisfactory manner. Experiments now under way give some promise. It is quite within the realm of the possible that new methods may become applicable to all classes of wood products and may revolutionize the entire art of seasoning, with tremendous benefit to producer and consumer alike.

A large percentage of lumber and other timber products will for many years to come be air seasoned despite any conceivable developments in the kiln-drying processes. Commercial air seasoning is exceedingly variable, has a large rule-of-thumb element, and has been too largely without investigative basis. While it is obviously impossible to vary the conditions to which the stock is exposed, it is possible to control the extent to which these climatic conditions affect the stock by varying such factors as the size and shape of the lumber pile.

The development of antiseptic chemical dips to minimize stain and decay, particularly during air seasoning, is a matter of immediate practical importance. The extent to which air seasoning loss can be reduced by such means and by proper yard practice varies considerably with the type of mill. Large mills can feasibly reduce damage to a negligible point if they so desire; small mills, on the other hand,

frequently are faced with the lack of any practically available method of preventing deterioration and consequently must suffer much larger unit losses than the larger operations. Since the smaller mills cut a large proportion of lumber that is subject to blue stain and are becoming production factors of increasing importance, especially in the Gulf States, the problem of devising efficient control methods for their use is one of real importance. Recent tests of antiseptic solutions give promise of yielding effective treatments that will be applicable to the use of small as well as large mills. Further work of this type is essential to insure the maximum satisfaction to the user of wood and the best returns to the producer.

The shipment, handling, and storage of lumber is another wide channel of loss for lumber values. Stock that has had the most careful manufacture and seasoning may suffer unaccounted increase in moisture content and attack by stain and even decay in its transit to the consumer via train, ship, and storage yard. The service of research can assist industry here by surveying the conditions of shipment and storage and recommending the proper safeguards against deterioration, similar in general to the measures which are effective in air seasoning.

CONVERSION

So many chemical and mechanical processes are involved in the conversion of logs into marketable products that they cannot be profitably discussed together. No consideration of products and markets is possible, however, without special recognition of the part these processes play. Conversion has received the greatest attention from within the forest industries themselves. It has undergone immense improvements, but it still stands to benefit greatly from continuing research. In the case of pulp, plastics, plywood, and dimension stock, conversion problems are touched upon elsewhere. Reference is made at this point only to lumber.

The larger sawmills operating on high-quality virgin timber have kept abreast of the most modern developments in machinery and methods. The losses in slabs, edgings, trimmings, and kerf are still substantial, but they have been reduced to the point where further reductions are extremely difficult. The pressing problems lie in the development of efficient units for the conversion of timber of a low quality and the smaller, scattered stands of virgin timber and second growth. Experiments indicate the practicability, under certain conditions, of an improved gang-saw mill and of a portable band mill to replace the present small circular mill. It has been shown that production costs can be reduced and the recoverable yield substantially increased through the use of these recently developed units. The possibilities in the portable band mill, in particular, need to be developed to the fullest extent and as rapidly as possible.

In all mills, improved technique for smooth dressing and surfacing is needed. Factors affecting the smoothness of surface, highly important to many uses, have been found to lie in the moisture content of the wood at the time of dressing and in differences in density and growth-ring structure. But only hints are now available as to the real solution of smooth surfacing free from tendencies toward raised grain and "fuzziness." Paint has been found to adhere better upon exposure to the weather if the lumber has been so cut that the bark

side is machined as the face for painting. As practical ways can be worked out for taking into account the peculiarities of wood as they come to light, the aggregate effect in satisfaction to the user will be distinctly beneficial.

LOG GRADING

Preparatory processes and conversion largely determine the degree of consumer satisfaction, but the log supply is of primary importance in production costs. To put different classes of logs into the product to which they are best suited and to exclude unprofitable logs are basic to low production costs. The logs coming from any forest vary greatly in size and freedom from defect. Judgment alone has been the basis of the sorting process to date, but it has not been sufficiently accurate to prevent large losses to manufacturers attempting to use unsuitable material. Rules of thumb can hardly be expected to show whether veneer, lumber, dimension, piling, or pulp is the product into which a given quality of log should go to net the largest return. The little amount of systematic study that has been given to this subject has shown that attractive prices for veneer logs, for example, have encouraged millmen to sell their best logs for that purpose, not realizing that the extra yield of high-grade lumber from those same logs would often net more than is obtained for them as veneer logs. As the production of diversified products becomes more common, it is particularly important to have a basis for sorting the raw material according to the product.

The need for the development and commercial adoption of log grades is becoming more urgent as time passes not only for lumber but for pulp and dimension, veneer, and other products cut from logs. The increasingly important part played by logs cut by farmers for sale to lumber, pulp, and other mills emphasizes the need for log grades. In the case of pulpwood, grading on the basis of weight rather than volume is a fertile field for improvement.

Rough log grades have been in use for some time, notably in the Douglas fir region, where logs are bought and sold on the open market. Preliminary investigative work has been done to improve these grades, as well as to develop log grades for southern hardwoods, but no really systematic program has as yet been undertaken in any case.

Closely allied to the grading of logs is their protection against deterioration from discoloring and decay fungi. Under poor conditions of storage and handling that frequently exist, injury occurs which may continue undetected into the finished product. While the immediate conversion of logs into lumber offers the surest way of avoiding deterioration, storage of logs in the woods or at the mill is common practice. Storage of logs in water or rapid seasoning by piling on high skids has been used with varying degrees of success in attempting to avoid fungus attack. The need for developing more effective methods of control was apparent, in the Gulf States region particularly, from a recent survey in which more than 50 percent of the mills visited had from 5 to 50 percent of their logs infected at the time of sawing. Recent tests of antiseptic sprays and end coating materials offer promise of yielding treatments that will combine fungicide with insect-repellant properties and will be commercially practical.

SELECTIVE LOGGING FOR SUSTAINED YIELD

Broadly speaking, all lumbering operations are carrying on without definite information as to which qualities and sizes of logs are yielding a profit and which are entailing a loss in conversion. Small trees that are being felled and logged at a loss would comprise the nucleus for a new crop if left to grow. A new complexion is given to present values when only logs and trees which pay their way are harvested. Intensive studies of Lake States hardwoods, southern pine, and western softwoods bring out clearly that operators are logging and milling timber which carries hidden losses as high as $10 per thousand board-feet. When current costs and returns are considered along with the facts coming from silvicultural studies as to rate of growth and proper methods of cutting, the way is open to markedly sounder economic practices than now prevail, and means are provided for decreasing the current overproduction of low-grade material and in giving so-called cut-over lands new values readily recognized by timber owners and bond and banking institutions.

The industry can make distinct improvements by operating on the basis of facts already brought to light. However, questions are involved that cannot be answered from present information. The investigations that have been made have dealt almost entirely with lumber as the product and with operating equipment designed primarily for large timber. Basic operating guides to the forest industries need to be worked out in the way of time-output values for each timber product as produced from different sizes and qualities of logs and trees. They need to be in such terms that varying wage scales, overhead charges, and market prices can be applied to them to give exact figures applicable to the individual operator.

LOGGING EQUIPMENT AND METHODS

Realization of the full economies in selective logging calls for certain changes in logging equipment. Despite the great advances in logging methods that have been made in recent years, particularly in the West, research has shown that the ultimate has not been reached. Large reductions in cost become possible when more flexible methods are used in connection with selective logging. From the detailed information already obtained it is found that tractor logging can be used to a larger degree than at present to reduce heavy expenditures for closely spaced railroad spur lines and for heavy skidders. Only a start has been made in the accumulation of detailed knowledge along these lines, but it is sufficient to show what may be expected as full information becomes available. Power saws also for woods operations have already made their appearance as a means of reducing costs, but their real merit over present methods remains undetermined.

The heavy loss in breakage in felling large timber in the West has been found susceptible of considerable control. Accurate examinations have shown that the breakage in the merchantable volume of Douglas fir and western hemlock varies from 3 to 16 percent according to the felling methods and the topography. Appreciable reductions in breakage can be realized, as the influencing factors of slope, bedding, direction of felling, methods of payment, and supervision are singled out and individually dealt with.

HARVESTING OF NAVAL STORES

The harvesting of the resin crop from the pine forests of the Southeast stands to gain greatly through the modernization of methods that science can contribute. Naval stores products have held their own in commerce and industry up to this point in spite of the unnecessary waste and the crude practices applied to their production. But it is now widely recognized that if they are to continue longer as profitable industrial commodities, radical changes must be made throughout the processes of production and handling.

The scientific study that has already been applied has shown the practicability of maintaining the flow of oleoresin by light, narrow chipping at as high a yield as by heavy chipping. The establishment of this fact makes possible longer working and greater returns per tree. Two to three successive workings for periods of 5 to 8 years each now result in less damage to subsequent wood products than resulted from the shorter workings commonly carried on in young stands. To a considerable degree these improved methods have already been adopted in commercial practice. That further modification might be made by changes in the frequency of chipping also give promise of future important developments. The size of the tree has been found to influence greatly the yield of gum, and the dividing line between profitable ane unprofitable sizes for working has been fairly well established. The vitality of tree growth is known to have influence in the yield of resin, but vigorous-appearing trees which might be expected to give high yields sometimes prove to be low producers, and small trees to be large producers. Thus, there are factors at work affecting the yields that have escaped detection. It is highly important to the intensive management that must henceforth determine the profits of naval-stores operation to avoid cumbering the ground with low yielding trees, which reduce the profits from the normal and high yielders. The question of the proper number of trees per acre is being given intensive study, since the spacing of the stand influences crown size and other basic factors responsible for the best yields of both oleoresins and wood.

Timber products as well as naval stores must be relied upon as the crop from forests of the Southeast, and the proper integration of all products becomes a matter of primary concern. Piling, poles, pulpwood, staves, and excelsior have been produced from the timber operated for resin. Continued outlet is threatened, particularly in the case of staves, whereas in pulp the outlet promises to increase. The margin, however, is so slight, even with substantial gains in pulpwood, that no outlet can be lost without serious consequences. The system of management which takes into account the varied products so as to make each contribute to the maximum net return from the forest has yet to be established. The facts required as a basis of such management are complicated and difficult to obtain, but the importance of getting them as rapidly as possible is obvious.

PULP AND PAPER

The production of pulp and paper deservedly ranks as one of the most important uses of forest material, and its importance seems destined to increase. As shown in the section "Timber Requirements", the total national consumption of paper and boards increased

steadily to 13½ million tons in 1929, and predictions made by various authorities place the annual requirements for 1950 anywhere from 24 to 30 million tons. Such a consumption would require an annual cut of pulpwood amounting, roughly, to 15 percent of our present annual cut of timber for all purposes. As a profitable use of large land acreages, the growing of pulpwood on a sustained-yield basis thus offers great promise for the near future.

It is not only as a quantity use of wood that pulp and paper manufacture takes an important rating. The quality and refinement of the product gives the industry a high labor and conversion factor, and the relative stability of its operations contributes to permanent community values. A recent study has shown that in the conversion of 1 million cubic feet of timber into lumber, planing mill products and boxes, 75 men were employed, $75,000 in wages was paid, and the resulting products were valued at $250,000; whereas, in the conversion of the same amount of wood into pulp and finally into a good grade of paper, the employees numbered 150, the wages were $200,000, and the finished products were valued at $900,000. The increasing dependence of the United States on foreign sources for its pulp and paper production is of considerable significance in this connection. As pointed out under "Timber Requirements", the quantity of foreign wood used in producing the paper consumed in the United States has increased steadily, until in 1930 the proportion had risen to 56 percent. In terms of wood use, the 1930 paper and wood pulp consumption of the United States was equivalent to approximately 13 million cords of pulpwood. Of this quantity, the equivalent of nearly 7,300,000 cords was imported. In terms of land use this means that perhaps 12 million acres of forest land in the United States were deprived of not less than a $50,000,000 contribution to the national market. In terms of labor employed, our 1930 imports of pulp and paper could be considered as equivalent to the "exportation" of full-time jobs for 70,000 American citizens.

Two main reasons may be assigned for this situation. The first is the present dependence of the paper industry upon a very few species. The second, which is related to the first, is the tenacious and long-standing concentration of the pulp and paper industry (the sulphate pulping group chiefly excepted) within easy transportation distance of the eastern spruce and hemlock forests and the large pulp and paper consuming markets. As the native supplies of northern and eastern spruce and hemlock have been progressively depleted, the natural tendency of large established industries has been to rely more and more on imports of these species from abroad (chiefly from Canada) or to move their mills over the border, rather than to migrate to distant regions of the United States and utilize new stands of similar or of different woods.

In view of the foregoing, the task of research in furthering the interests of our domestic pulp and paper production is clear. This is to increase the possibilities of economical production, higher yields, and better pulp quality from our native woods, both those now preferred for pulping and those not now used extensively or not used at all. Its accomplishment must be based on a varied research attack, for which the following lines are suggested:

1. Improvement of present pulping processes or the development of new processes to increase the usefulness of present pulpwood species.

2. The application of pulping processes to new species.
3. Increase in efficiency and knowledge of the fiber processing operations—beating, bleaching, refining.
4. Investigations of the variables of paper manufacture and of the mechanical factors underlying sheet formation and the production of finished papers.
5. Effective utilization of woods and mill waste.

The wood-pulping industry as it exists today has largely been developed by research, and the difficulties that the domestic producer has lately experienced in meeting foreign competition can be removed, not by less research but by more research, better integrated and consistently followed up in production.

IMPROVEMENT OF PULPING PROCESSES

The so-called standard pulping processes include three of chemical nature known commercially as the soda, sulphate, and sulphite methods. The first two are alkaline and the third is acid in character. The fourth process is strictly mechanical, disintegration being accomplished by means of a grindstone. A large volume of empirical research underlies the standardization of these processes throughout the American pulp and paper industry. There is a great need, however, for more fundamental information on the physical and chemical laws involved in pulp production by these standard methods than yet exists. Such objectives require intensive and continued research, which will coordinate knowledge of raw materials and chemical reagents with a fundamental picture of the reactions occurring in the pulp digester and of the effects of the disintegrating agency, such as the grinder stone. Studies in connection with both the chemical and the mechanical processes have resulted in material improvements, with results in increases of yields and improvement of pulp quality. However, only a beginning has been made, and immense returns should result from a continuation of this line of effort.

NEW PROCESSES

Studies of established processes logically lead to the development of modified or new processes. A recent step in this direction is the replacement of the lime in the normal sulphite method by soda or ammonia, resulting in the extension of the application of the sulphite process to more resinous species. This development has required the working out of a recovery system which will return the more expensive chemicals cheaply and at the same time alleviate a serious situation in stream pollution which now confronts the sulphite pulp industry and is a menace to aquatic life in our lakes and streams. Increases in the quantity of pulp returned per unit of wood have been effected through new semichemical pulping processes, which are combinations of chemical and mechanical action on wood. Whereas the standard chemical methods return only about 40 to 50 percent of the wood as useful fiber, the new methods return from 55 to 80 percent. A so-called semi chemical process using neutral chemicals, a semisulphite process using acid sulphite liquors, and a semisulphate process using alkaline reagents have all been developed in the course of work on this problem. On account of their high noncellulose content, the semichemical pulps are unbleachable by present methods and are limited in their application to light-colored woods or to the production

of pulps in which color is a secondary consideration. Even under these limitations, however, the processes are finding their way into important commercial use.

PULPING NEW SPECIES

The need for extending the range of species for pulping has long been recognized, and a systematic survey has been conducted by the Forest Service covering about 100 American woods as regards their adaptability to standard pulp-manufacturing processes. Comparative data have been compiled as to yields, chemical consumption, bleachability, and other factors of pulp production from the various species, but the information is necessarily limited and somewhat in the nature of a "base line" for further intensive studies. The specific characteristics and economic importance of a given species determine the special studies to be undertaken.

The principal weakness disclosed in previous efforts to improve the pulping and papermaking status of particular species has been a lack of what may be termed fundamental information—lack of accurate knowledge of the chemical composition and minute physical structure of the wood, of laws underlying the behavior of pulps in processing, and of the basic factors in paper manufacture. A great mass of empirical data has been built up at the Forest Products Laboratory and at the mills that is applicable to a given species or a given process, but basic information of general application is largely lacking. Work to supply this need is going forward, but it should be greatly increased.

From the standpoint of regional distribution, various types of species have to be considered. In the Northeastern and Lake States, the prevailing softwood types—spruce, fir, and hemlock—have been the mainstay of the American wood-pulp industries, and the direction of progress in the utilization of these species lies in the improvement of the present standard pulping methods or the discovery of new processes that may increase yields and cheapen production. The pines and other species high in resins and extractives that are found in this region offer the same problem as they do elsewhere, namely, how to convert them cheaply into light-colored papers of general utility. The stands of second-growth hardwoods (made up largely of maple, birch, beech, and aspen) that have sprung up following the logging of earlier stands of pulpwood and saw timber throughout a vast acreage in these regions are a potential source of pulpwood. They are of small diameter and of very inferior commercial value at present except for limited uses in soda and mechanical pulping. A much more important use for them is visualized in the form of sulphite or other pulps of wider usefulness and value. Experiments on these lines have been carried forward with considerable success, but the short fiber of the hardwoods still militates against their use in strong papers. It has been shown recently, however, that in the grinding of hardwoods, a proper dressing of the stone surface will accomplish disintegration of the wood with minimum destruction in the fiber length, thus resulting in improved pulps. It is likewise indicated that the high pentosan content of these species may be utilized, if retained in chemical pulps produced from them, to produce much stronger papers than has hitherto been thought possible.

A vigorous and growing pulp industry exists on the west coast. The bulk of the raw material used is western hemlock, which enters into a large production of newsprint, wrapping, and other papers. In this region the utilization of sawmill waste is an outstanding feature, but certain major problems of integration between woods operation, sawmill, and pulpmill remain to be solved. Douglas fir, for example, stands at the top of western lumber production. Its immense cut is attended by immense waste, estimates indicating that, in an average year's logging, 6 million cords of material of pulpwood size or larger is left in the woods unused. This amount, if it could be converted into pulp, would nearly duplicate the present annual pulp output of the country from native sources. If even a third of it could be profitably pulped, American industry would have an immense resource of cheap raw material with which to combat foreign competition, and a commensurate value would be added to our national income. An approach has been made toward solving this problem. One mill in the Northwest is successfully producing bleached soda pulp from Douglas fir for use in book and tablet papers, and several of the sulphate mills in the same region are consuming small amounts of mill waste in the production of kraft papers and kraft boards. The quantity of material thus utilized, however, is insignificant in relation to the available supply and reflects certain difficulties in the pulping of Douglas fir which are the subject of investigation at a number of sources. Some success has recently resulted from modifications of the standard sulphate process by which stronger and better-bleaching pulps have been made, but much remains to be accomplished in this direction.

Additional research on the production of sulphate, sulphite, and mechanical pulps from western hemlock and from a large number of other western woods which hold special promise for papermaking purposes is needed to place western pulps on a full competitive footing with the imported products in the Nation's markets. Among the western species important in this respect are California white fir, ponderosa pine, Sitka spruce, lodgepole pine, redwood, and western larch.

In the South the various species of yellow pine hold the premier position in both lumber and pulp production. Nearly four fifths of the total capacity of southern pulp mills (1 million tons annually) is devoted to producing, from pine, pulps of one main type—unbleached sulphate or kraft. The successful conversion of these difficult resinous species is itself a triumph of research and experiment, but research may have here a more far-reaching result. This is nothing less than to establish in the South the final and perpetual margin of independence for the United States from foreign paper imports.

The South has more than 100 million acres of cut-over pine land which, given proper forest management, is conservatively estimated as capable of producing from one half to 1½ cords of wood per acre per year—a sufficient volume in the aggregate to match our present pulpwood consumption 5 or 6 times over. The problem is, from this potential pulpwood supply, to develop papers of the types required in our national commerce.

Starting with the established fact of a large southern pulp production, the Forest Products Laboratory has evolved a modified kraft

process by means of which most resinous species can be converted into strong, light-colored multipurpose pulps. Whether the economic trend will carry this process into large production at an early date or whether a still cheaper and radically different process will find ultimate adoption cannot be foretold in the present state of affairs, but at least a beginning has been made toward solving the problem of diversified southern pulps. Furthermore, by taking advantage of the fact that young-growth slash pine up to about 25 years of age is free from heartwood and is comparatively light-colored, both of which factors are favorable to the application of the sulphite and mechanical processes, there appears a possibility of developing a pulp suitable for newsprint, cheap book, magazine, tablet, light-colored wrapping, and similar papers. All of these types of papers have been produced experimentally from mixtures of sulphite and groundwood pulps from young slash and shortleaf pines. Young growth from other species can probably be similarly used.

Certain southern hardwoods are also apparently potential sources of pulp and paper. Black gum, for example, has been proved to be an excellent base for sulphite or semichemical pulps possessing potential usefulness as a raw material for newsprint as well as for fine papers.

The realization of improvement in use of species now used for pulp or the increase in the number and extent of species which may be used in pulp and paper products must be based on a varied research attack. The following avenues are suggested;

FIBER PROCESSING

Under the head of fiber processing are included the operations of bleaching, beating, loading, sizing, coloring, refining, and any others incidental to converting a pulp into a stuff prior to its run over the paper machine. Each of these operations is virtually a separate field of technology, in which research and long experience have developed the art to varying degrees of excellence. Continued and systematic research is needed to secure higher and more uniform standards of quality, strength, color, and sheet formation.

Fundamental and detailed investigations of the bleaching process have been carried on for a number of years. The several aspects of the problem studied include the effects of temperature, chemical ratio, and consistence upon rate of bleaching, composition, yield, and final color of the pulp. The objective of all such work is to place the bleaching operation on a basis of rational procedure and predictable results and to clear up the confusion, uncertainty, and empirical opinion that has quite generally made bleaching a craft mystery instead of a definitely controlled technical operation. Commonly in commercial operations the pulp is cooked so thoroughly that only small amounts of bleach are required. A thorough investigation is badly needed as to the possibility of modifications of both cooking and bleaching to give higher yields and whiter and stronger pulps. Some progress has been made in this direction through the development of two-stage chlorination bleaching procedures. The further commercial development of such methods, particularly as applied to the pine pulps, would greatly stimulate the use of these pulps and would distribute pulpwood demand more widely.

Research on the beating of pulp has thus far been limited mainly to attempts to place beating equipment under control, so that the opera-

tion could be performed in the same way on any given pulp. Methods of really measuring the effects of beating are lacking and must be developed. It is not even known with certainty whether "hydration" as known to the paper maker is a chemical or a mechanical effect.

PAPER MACHINE OPERATING FACTORS

The best-directed efforts to produce a pulp that will make paper of excellent quality can be defeated by faulty machine operation. Tests indicate, for instance, that the strength of sheets can be lowered 33 percent and porosity increased 100 percent by draw manipulation alone. In order to put the papermaking procedure on an engineering basis as free as possible from purely empirical practice, research looking to the isolation, measurement, and control of the machine operating factors is essential.

This is no simple task. At least 75 independent or dependent variables have been identified on the paper machine, a few of the more important being consistence of stock passing to the wire, relative speed of stock and wire, effect of stock temperature, hydrogen-ion concentration of the stock, rate of drainage to effect formation, couching pressure, rate of moisture removal in presses, drying rate, amount of draw, and calender pressure.

MILL WASTE UTILIZATION AND WASTE PREVENTION

Large opportunities for operating economies and increased returns await the work of practical research in the utilization of wood-room wastes and mill effluents. Bark has ordinarily been a total waste in pulp manufacture. A small amount of investigative work has been done to develop methods of using bark for fuel or for special products. There is need for much more. It is estimated that wood fiber to a value of $10,000,000 goes down mill sewers annually, suspended in the "white water" discharge. This waste would not occur in the line of ordinary business if the over-all economy of saving it could be demonstrated in general practice. A third obvious line of economy in production is the utilization of spent liquors. The savings possible in the reuse of waste sulphite liquors in a second pulping treatment have been partly demonstrated, and still greater gains lie in the possible utilization or recovery of sulphite liquors now discharged, containing as they do all the chemicals of the pulping reaction and a full half of the raw material.

Determined efforts should continue toward the elimination of fiber losses due to the decay of pulp and pulpwood. The latter is subject to deterioration from the time of cutting until it is delivered to the grinder or chipper for conversion into pulp. Under commercial conditions of handling, deterioration of wood is particularly rapid in the second and third years of storage. A further source of loss is the reduction in quality due to the deterioration of the pulp into which the wood is converted. While the development of antiseptic chemical treatments and of improved methods of handling pulp and pulpwood have aided considerably in reducing losses, work is still needed to insure commercial applicability of research findings. In addition, the use of new woods and the changing conditions and methods of handling continue to introduce new problems of deterioration that demand study.

WOOD—ITS STRUCTURE, COMPOSITION, AND PROPERTIES

Wood is both a finished natural product and a storehouse of raw materials. It is a fibrous aggregate containing cellulose and other carbohydrates, lignin, and extractives, combined in variable quantities and arranged in a complicated and variable microscopic structure. There are 150 important species of wood in American forests, each differing from the others in structure and properties, and each varying within itself to a considerable degree. The chemical composition of wood substance, the arrangement of the constitutent parts in the wood cells, the size and spacing of the cells, and the variation of all such characteristics according to species and growth conditions determine the usefulness of wood as such and its potentialities of conversion into other products. A scientific understanding of these matters opens the way to success in the silvicultural control of the material and its properties, in its selection, its seasoning and handling, its impregnation with preservatives, its use in construction, and its conversion into pulp and other products.

To visualize and emphasize the complexities and importance of research that lies ahead in these fields something of the facts at present known and the main lines of further study required will be briefly reviewed.

STRUCTURE OF WOOD

The structure of wood is so complex and variable that an adequate conception of it cannot be conveyed in a few words. Essentially it is a cellular structure, but there may be several different kinds of cells with different arrangement and different means of intercommunication. Most of the cells are arranged longitudinally, parallel to the tree trunk, but some extend radially. Beyond this cellular structure, plainly visible under the misroscope, are smaller structural units. The cell walls are made up of concentric layers, which in turn are composed of fibrils arranged spirally. The fibrils are the smallest units that become evident through any simple mechanical disintegration, but by careful chemical treatment they themselves may be subdivided into spindle-shaped "fusiform bodies" and the latter into minute spherical units. The spherical unit—the ultimate visible component of the cell wall—is about one hundred-thousandth of an inch in diameter, and beyond it the microscope cannot penetrate. It is possible, however, by indirect methods using the ultracentrifuge and the X-ray, to determine the approximate size and arrangement of submicroscopic units.

The arrangement of these various parts to form the cell wall, the shape and size of the various cellular structures, and their arrangement and mode of joining to form the wood determine completely the gross mechanical properties of the material. The submicroscopic units and the peculiar attractive forces between them give wood its colloidal properties, such as hygroscopicity. This absolutely basic field of wood research is largely unexplored. It abounds in hypotheses of colloidal behavior which await experimental verification and correction. Other more specific structural research is concerned with the means of communication between the cells. The cell cavities are separated by thin pit membranes through which there are openings of submicroscopic size that can be measured only by indirect methods. The number, size, and location of these openings, together

with the colloidal properties of the membrane itself, are thought to control all natural or artificial movement of liquids within the wood, but no satisfactory theory of their action has as yet been worked out.

Even in regard to those types of structure that are readily visible in wood sections under the microscope, quantitative statistical information that has a realistic bearing on the properties and utilization of wood is very meager. Much more research is needed before the picture of wood structure and substance as an industrial material can compare, for instance, with that which the metallurgist has obtained for such materials as steel and copper.

CHEMISTRY

As to the chemical composition of the various structural units of wood, information is likewise far from complete. It is known that the structural units of the cell wall are essentially cellulosic in composition. It is thought that a small amount of lignin is incorporated with this cellulose structure, but the details of its distribution there are not known. Lignin, however, comprising approximately one third by weight of all wood substance, is the main constituent of the cementing layer between the cells. There is present in the wood a considerable percentage of carbohydrates other than the cellulose whose location in the structure is unknown, and finally there are extractives or infiltrated substances that are variously distributed, either in specialized structures such as the resin ducts of certain species or in the cell cavities, or more or less evenly disposed throughout the cell wall.

As distinguished from the chemistry of its minute structure, the general chemistry of wood is fairly well known in terms of the gross chemical groupings already stated. But even in these limited terms there is little statistical information on the variations in composition between species, within species, or within single trees. Moreover, much additional information is needed as to the chemical composition of the main groups, cellulose, lignin, etc. The term "cellulose" as used here comprises a group of similar carbohydrates that make up about 60 percent of the weight of dry wood. Only about three fourths of this "cellulose" is true cellulose, however. The remainder is made up of different sugar units put together in somewhat less stable form, and our little knowledge concerning their constitution and the nature of their combination is entangled with a mass of speculation. Even less is known about the group of carbohydrates not closely associated with the cellulose that make up about 5 to 10 percent of the wood.

Lignin remains an unsolved mystery. Many isolated facts are known in regard to its chemical characteristics, but they do not form any clear or connected picture of its constitution. Probably it is not a single chemical substance but rather a loose grouping of similar substances in variable proportions.

The extractives are really matter outside the mechanical structure of wood, but they are important in connection with many of its properties. Color, odor, and durability are basically dependent on extractives, while pulping, painting, gluing, and even strength properties are considerably affected by them.

They vary widely in both amount and composition, such different classes of chemicals as resins, terpenes, tannins, gums, carbohydrates,

and dyestuffs being common amongst them. While the detailed composition of the extractives in some few species is well known, it is incomplete or entirely lacking in most.

MECHANICAL AND PHYSICAL PROPERTIES

The mechanical characteristics of wood—its strength, elasticity, and related properties—depend on the physical properties of the structural units, their arrangement, and mode of joining. The structure of wood is so complex, however, and the structural units so small, that the mechanical properties have not been actually determined in any such manner, but instead have been directly measured by standard engineering testing methods. The various important strength values of the 160 principal American woods have been determined and general rules developed for the effects of density and moisture content. This kind of information is fairly complete, although more information on the range of values as well as the average values, and on second growth as well as virgin timber, would be desirable. There are also two important commercial properties, resistance to abrasion and workability under tools, for which no figures are available.

The information that we possess as to strength properties has been collected with only incidental reference to structure; the direction (longitudinal, radial, or tangential) in which the force was applied was commonly known, and one structural characteristic, density, was always determined. The finer details of structure were not determined, however, nor were the tests designed to show the effect of structural variations in any minute degree. This kind of work, only recently undertaken, has naturally begun with the influence of the largest unit structures, the two layers of the annual ring, spring wood and summer wood, upon the strength of the piece. Much remains to be done even in this field of gross structure, and then more complicated fields of smaller units, such as the thickness of the cementing layer of lignin and the slope of the spiral angle of the fibrils, must be developed before scientific knowledge of the relation between structure and strength can be considered at all adequate.

There are other types of scientific details in wood mechanics, knowledge of which would be very desirable. For instance, wood is not truly elastic but has a tendency toward gradual plastic yielding, and it is important to know whether the plasticity has its origin in the cellulosic fibers, in the lignin cement, or in shear between the fibers.

Other physical properties as distinguished from the purely mechanical are also obviously dependent upon the minute structure of wood. Among these, heat, acoustics, electrical properties, and hygroscopicity are outstanding. None has received thorough or systematic study.

The handbook figures for heat conductivity of wood are incomplete as to species, moisture content, direction of the grain, density, and temperature boundaries. A few accurate determinations have been made on the effect of some of these factors, but not enough to give the architect or engineer the specific information he requires in order to determine what wood to use or whether to use wood. Heat conductivity also has important bearings on the fire resistance of wood in large sizes, on wood distillation processes, on the preheating preceding impregnation treatments, and on other important industrial

operations. What little has been accomplished in theory and technique has not been adequately applied to wood as a construction material where control of acoustic properties is required. Further knowledge of the electrical properties of wood might seem to be unimportant in direct application to uses of wood, since wood in its unmodified state is not reckoned as either a good conductor or a true insulator. Research on electrical properties has, however, been of great assistance in solving other problems, such as the measurement of moisture and the determination of the submicroscopic pore volume of wood, so that, indirectly at least, further knowledge of electrical properties would be of value.

The great importance of a complete and detailed scientific knowledge of hygroscopicity is evident from the fact that it affects every other physical and mechanical property of wood. The water in wood occupies two different kinds of cavities, the microscopic cavities and the extremely small spaces between the submicroscopic structural units. The larger cavities remain as cavities of the same size whether they contain water or not, but the smaller cavities decrease in size according to the amount of water removed from them. The lowering of the vapor pressure of the water in the latter is the basis for the hygroscopic property of wood—its ability to absorb water from the air—and their change in size is the basis for the swelling and shrinking of wood with change in content of hygroscopic water.

This hypothesis of the cause of hygroscopicity and shrinkage is tentative and imperfect because there are so few facts from which to develop it. For a satisfactory understanding of these phenomena, intensive research is required on such diverse subjects as the hygroscopicity of different components of wood, directional shrinkage of the structural units, hysteresis effects, absorption of other liquids than water, and diffusion of hygroscopic water.

GROWTH CONDITIONS

The proper and satisfactory use of wood has had to depend on selection from a widely varying natural product in order to obtain the different kinds of material required. In this respect it is fortunate that wood is a widely varying product. From another point of view, the use of wood would be less a problem if its properties and minute structure could be controlled in somewhat the same manner as the metallurgists controls the quality of metals in manufacture.

Such control of the raw material, wood, lies in controlling the conditions of its growth. Distinctive species characteristics cannot be changed, but within the ordinary variations of a species wood of more uniform and more desirable properties can be grown.

The existing information on this subject is very slight in view of the wide field to be covered. There are so many species, properties, and growth conditions that the complete correlation of all or even the most important of them will take a large amount of research. It has been found that with longleaf pine the proportion of summerwood to springwood (and hence density and strength) can be varied within limits according to the amount of soil moisture available. In second-growth southern pines the increased rate of growth that accompanies increased openness of stand causes a decrease in the density and strength of the wood, and the indications are that this relationship holds for the softwoods as a class. In hardwoods, on the other hand,

it appears that reduction in strength may occur when the rate of growth is slowed down by crowding of the stand. Thus some of the most readily controlled growth conditions are found to have important effects on wood properties.

The effects of growth conditions are brought about through the physiological processes of the tree, which must be much better understood in order to lay a proper scientific foundation for further work. The source and nature of the food supply, its elaboration into intermediate and final products, its translocation to point of final use, the transpiration process, storage of reserve materials, and moisture and temperature limitations are some of the important physiological factors about which the existing information is fragmentary.

The special physiological processes involved in resin formation are of great importance in connection with the production of turpentine and rosin from longleaf and slash pines. Research on the development of the resin ducts in response to the wounding of the tree has already assisted in improving chipping methods so that better yields can be obtained with less injury to the tree. Further improvements depend on more detailed knowledge of the physiology of resin formation.

WOOD-DESTROYING ORGANISMS

There is another type of fundamental research that is not concerned directly with wood but instead with the various organisms that attack wood under certain conditions of its use. The three principal groups of such wood-destroying organisms are the fungi, the insects, and the marine borers. The fungi are responsible for the well-known decay and staining of wood, while insects and marine borers destroy wood in the course of using it for both food and shelter. Further improvements in methods of protection against these organisms require a fuller knowledge of their life history and habits, and especially of the conditions favorable and unfavorable to their attacks on wood. It is known, for instance, that wood may be too wet or too dry for wood-destroying fungi to attack it, but the limits of moisture control between which they are active are not known with any accuracy.

Such fundamental biological research may have fairly direct practical application, since many if not most of the difficulties with these organisms are caused by faulty practice in cutting, manufacture, or storage of the wood or in the design or condition of use of the final product—faulty practice that can frequently be improved or perfected simply and cheaply when there is sufficient knowledge of the limitations of the organisms. Biological research is especially important with fungi, because of the multitude of species that attack wood and the great variation in their characteristics.

Biological research on wood-destroying organisms may also be of value for the purpose of producing chemicals from wood. Molds and bacteria have been recently found that under controlled conditions produce acetic acid, lactic acid, ethyl alcohol, and other higher acids and alcohols from cellulose, and it is possible that similar products could be thus obtained from wood cellulose or direct from wood. Certain organisms attack lignin but, so far as it is now known, without forming useful products.

FUNDAMENTAL RESEARCH AND UTILIZATION PROBLEMS

Fundamental research on wood structure, composition, and properties is of controlling importance to improved wood utilization and to studies having direct practical applications. The relationship is obvious. For selection of material, knowledge of wood structure and its effects on strength and physical properties will give a scientific basis far in advance of existing standards. In the many uses requiring modifications or adptations of the material, such as impregnation, gluing, and painting, a knowledge of the cell and its parts and of the movement of liquids from one part to another will make possible better, more economical, and more efficient processing and better service of the product.

An adequate knowledge of the chemistry of wood is necessary for the development or improvement of chemical processes of wood utilization, including the manufacture of pulp, paper, rayon, and plastics. In this field lie the greatest possibilities of new wood products for new uses. Full understanding of the chemistry of wood as related to biological factors opens the way to processes of conversion that may prove cheaper and more efficient than any now known.

In brief, it is through the methods of fundamental research, largely neglected hitherto as far as wood is concerned, that we must look for future significant progress in technical guidance to improved products and practices and for the development of new products. No one can gainsay the effectiveness of such research until the undiscovered world of wood fundamentals has been explored. To this end the concerted efforts of the chemist, the physicist, the biologist, the bacteriologist, the engineer, and the silviculturist must be intensively applied, with all the tools of modern science such as the ultracentrifuge, the X-ray, and the ultraviolet ray, and all the adptations of the new instrumentalities that research is learning to effect in the sphere of atomic behavior.

COOPERATION IN FOREST PRODUCTS RESEARCH

On account of the many fields in which forest products research is needed and the large and urgent problems remaining unsolved in each, it is obvious that the work ahead presents a responsibility for many agencies. By no means should it be considered the task of any single group or organization. The concerted and best-directed efforts of all agencies that have a defined interest in the forest program is called for. This means full participation not only by the Federal and State governments, colleges, and endowed institutions, but also and especially by private industry concerned with the manufacture, marketing and use of forest products.

The manufacture and distribution of forest products is all in private hands. Many concerns are too small to engage in the research necessary for highly efficient operations, but many are large and have obligations which are now being met only in small part. The competitors of wood, by using research, force similar action upon the forest industries. The private operator cannot depend upon others for all the research he will need. Research organizations sponsored by industry cannot be created or developed too rapidly.

The States should make a large contribution to forest products research because of their expanding ownership of forest land, which

has already reached millions of acres in State forests and other holdings. In addition, practically every State has its local forest production and marketing problems which it cannot expect the Federal Government or any other agency to solve except in small part. These include the local problems of unorganized small producers and owners unable to support research except through their contributions to the public taxes. The reasons for a substantial contribution by the States are much the same as in agriculture, and in fact the management and profitable conversion of the farm woodlot is in one sense a promising but largely undeveloped form of diversified farming.

State universities and State agricultural colleges, even though they contain no forest schools, can and should be engaged in one or more phases of forest products research in their engineering, biological, and chemical laboratories. What most if not all the forest schools in such institutions need is larger faculties, from the standpoint of investigative work alone. It would be an excellent thing if all such forest schools could have at least one man with full time or practically full time and suitable equipment available for products research.

The Federal Government already makes a relatively large contribution to forest products research, and a question may justly be raised concerning the obligations of the Federal Government which would justify any large increases.

Many phases and characteristics of the forest utilization problem of the United States are interstate or national. Everyone uses wood directly or indirestly, regardless of the accident of residence. Many phases of better utilization and waste prevention are national problems along with timber growing. The multitude of small manufacturers and small users, including farmers, involve exactly the same considerations as in agriculture from the research standpoint. The national distribution of our pulp and paper manufacture, which would relieve over-centralization in one or two regions, is merely one of a large number of problems which are national or regional, or both. On a realistic analysis, the continued and increased participation of the Federal Government must be taken for granted in any far-reaching program of research aimed at stabilizing and expanding wood consumption in the United States. Government pioneering and success in forest products research, particularly by the Forest Service, stands as an accomplished fact.

The opportunities and needs of endowed universities with respect to forest products investigations are similar to those of State universities or agricultural colleges. Larger faculties and equipment are needed, partly for more effective instruction but chiefly to permit more research. In the various departments of endowed universities with forest schools, and likewise in universities which do not contain forest schools, there is still a very large opportunity for faculty or graduate-student or fellowship research on a wide range of forest problems. If such institutions will encourage research in forest products they can in the aggregate contribute materially to our progress in forestry.

Several research institutions, such as the Mellon Institute and the Institute of Paper Chemistry, already include in their investigative field one or more phases of the forestry problem. The field covered by such institutions should be broadened and the number should be increased. They can be assured that almost anything in forest

products research which they undertake will be of benefit directly or indirectly to forestry, and hence to the public welfare.

In brief, there is room and need for the intelligent effort of all agencies; public and private, in the too-much neglected field of forest products research. Cooperation, the broadest possible interchange of information, and avoidance of overlapping effort should be the keynote. Each research agency or class will make a more or less distinctive contribution in this research structure. Private owners and industry will concentrate chiefly on their own localized problems and on the application of more general findings to their conditions and requirements. The States will necessarily work in part on somewhat more generalized problems, but ordinarily not beyond those peculiar to their own territory. An important State function will be to serve large numbers of small owners and operators who cannot be expected to support forest products research except through taxation. State institutions should also work on those fundamental problems which underlie their own needs. The Federal Government must attack regional, interstate, and national problems, and many phases of fundamental work. The national forests alone place a heavy obligation for forest products research upon the Federal Government. Endowed institutions will in most cases work on selected problems or some phase of fundamental research.

MEETING THE CHALLENGE OF CONSUMPTION TRENDS

The measures advocated in the foregoing constitute a plea and a program for placing the whole structure of forest markets on a revised and modern basis of consumer-service and continuing supply.

It cannot be denied that in certain fields of forest consumption the recent trends, aggravated by depression, have been discouraging to producers. They have been prolific of waste, excessive competition, and reckless liquidation of holdings. The situation presents obvious problems which are of fundamental importance to the future of commodity forestry.

On the other hand, it is submitted that changes in demand are to be recognized, not combated. Old-fashioned exploitation of what were formerly "exhaustless" timber resources is not and cannot be the solution of the marketing problem, as both forest demand and forest supply enter upon the modern era and modern conditions. It is imperative that costs within the industries be lowered, to give the consumer the benefit of economical and abundant products and at the same time to cure the ills of unprofitable production and management; that the quality and service properties of the products be largely improved and better discriminated, to insure maximum satisfaction in use; that the development of new products be pushed forward to take full advantage of the tide of modern demands and preferences; and that sales and promotion policies be intelligently and aggressively directed in relation to these same objectives.

Some of the ways and means of meeting the modern challenge have been set forth with at least sufficient clarity, it is hoped, to indicate the direction of progress. It is believed that management and marketing activities may well be concentrated with special reference to transportation costs. The costs of raw material and manufacture should be reduced and quality of output improved by

selective logging, and the productiveness of stands should be extended through management for sustained yield. In line with technical efficiency in the use of materials, the trend toward integration of forest-using industries in favorable locations should be encouraged, while wastes in all departments must be further reduced. Production from small holdings must be improved and adjusted to meet the standards of orderly manufacture and marketing, and merchandising must be activated on the modern plane of quality standards and technical requirements.

The apparent "encroachment" or "intrusion" of other materials in fields of wood use has been shown to be an inevitable expression of the modern age and the eagerness of consumers for new and improved products and services. The need and the responsibility for more scientific and technical research in wood and its products have therefore been specially stressed. Some of the more obvious and urgent objectives which research should follow have been pointed out—better construction and fabrication, unit construction, better treating, coating, and gluing processes, better conversion and harvesting, keener selection and grading, the improvement of pulping processes and machine operations in paper manufacture, the development of plastics and other new and special products, basic and fundamental studies of the nature and minute characteristics of wood, and the cooperation of all agencies, commercial and public, in the prosecution of these and allied lines of investigation.

By girding themselves to meet modern demands efficiently, forest industry and forest ownership can look forward to a continued place of major service in the country's economic life. The public has lifelong need for, familiarity with, and attachment to wood and wood products. The Nation has a vast program of forestry at stake in the trend of wood use. The fiscal stability of local governments is bound up with profitable use of the land. The weight of public preference will be a mighty factor that may well be cultivated in stabilizing and enlarging forest consumption and in safeguarding forest markets. It may be counted on to give wood a "fair deal." In return, forest industry must make sure that wood shall meet a high standard of expectation and performance, and that forest resources shall be constructively used and the supply continuously developed in accord with the general welfare.